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Mapping visual input onto lexical entries in the bilingual mental lexicon in the language switch condition

This paper studies the influence of language-specific elements in visual stimuli on the reaction times of bilingual speakers at the moment of the language switch. Premises of the models of bilingual language processing BIA and BIA+ are studied in terms of their different views upon the language switch cost and the predictions the models make about the influences factors within and outside language have on bilingual processing. Croatian-English dominant bilinguals carried out a lexical decision task in which four independent variables were controlled: language of the stimulus (Croatian/English), language switch (language switch/no language switch), language specificity of the visual elements in the stimuli (language-specific/language-nonspecific), and stimulus type (word/pseudoword). The interaction of the given variables was looked into; the participants' reaction times to the stimuli with and without language-specific elements in the language switch and the nonswitch conditions were compared. According to the results, language-specific elements in the stimuli did not influence the language switch condition; however, no language switch cost was found either. Such results of the visual processing of Croatian-English dominant bilinguals were interpreted in terms of the premises of the BIA+ model into which the basic predictions of BIMOLA, the model of bilingual auditory processing, were integrated.

Key words: language switch cost; language-specific elements; Croatian-English dominant bilinguals; BIA; BIA +; BIMOLA.

1. Introduction

When a visually presented word is perceived, its orthographic representation is mapped onto the information the reader has about this presentation in his/her mental lexicon (lexical entry). In the mental lexicon all the information about the words of one's language(s) is stored. The process of accessing the mental lexicon to map visual information onto the corresponding lexical entry in the mental lexicon is known as lexical access. This paper deals with lexical access in the bilingual visual processing of isolated words in Croatian-English dominant bilinguals. They are dominant in Croatian, their mother tongue, and they use their English language regularly and actively in academia and in their leisure time. In bilingual processing both languages are highly active and switching between them may take place (Grosjean 1998). However, it has been shown that processing gets slowed down at the moment the language of the processing changes (Von Studnitz, Green 1997). This phenomenon is known as the language switch cost. On the other hand, it has been suggested that language-specific cues (LSCs) in the stimulus may direct processing to the appropriate language of the speaker in the language switch condition, thus helping the system overcome the processing strain which occurs at the moment of the language switch (Grainger, Beauvillain 1987). LSCs are elements of orthography (or phonology) specific to one language and inexistent in the other language studied. Language-specific orthographic cues (LSCOs) can be single letters, combinations of graphemes, etc. In auditory stimulus, language-specific auditory cues are prominent and numerous and they can be found at the segmental and the suprasegmental levels. Should it occur, the facilitating effect of LSCs would be visible in the reduction of the language switch cost. The focus of this paper is on the language switch condition and its effects on visual bilingual language processing as well as the disputable influence of LSOCs on the reduction of the language switch cost.

2. Language switch in bilingual language processing

The theoretical framework of this study rests upon the predictions the Bilingual Interactive Activation model (BIA) (Dijkstra, Van Heuven 1998) and its upgraded version, the Bilingual Activation model + (BIA+) (Dijkstra, Van Heuven 2002) of bilingual language processing give about the reasons the language switch cost occurs. The design of the BIA model presupposes the existence of four levels of processing representations: the feature level, letter level, word level and the language level. The information flow is directed both bottom-up and top-down,[1] allowing language nodes to exert top-down influence on the processing. When ac-

[1] Bottom-up processing is such perceptual processing in which sensory (visual) information prevails, while top-down processing is such processing which draws on the contextual information (Horga 1996: 135).

tive, language A node inhibits the words of language B and spreads activation onto the words of language A thus causing negative effects in the processing of language B at the moment of the language switch (Grainger 1993). Such predictions situate the switch cost within the word identification system. However, some researchers suggest that the switch cost is conditioned outside the mental lexicon, in the task/decision system (Thomas, Allport 2000). The role of the task/decision system is to determine the steps or operations necessary for carrying out a particular task (original concept in Green 1998). The BIA+ model predicts that the previous stimulus list composition and participant expectations may affect the top-down task/decision system. In contrast, in BIA participant expectations do not exert strong effects on the activation state of words (Dijkstra 2005: 188). Both the previous stimulus list composition and participant expectations are treated as non-linguistic context in BIA+. Non-linguistic context is connected to the task/decision and not to the word identification system. As opposed to the BIA model in which language nodes spread top-down activation onto the units of the previously used language and inhibition onto the units of the previously unused language, in BIA+ the task/decision system predicts no top-down influence on the word identification system. The information flows bottom-up, and language information becomes available only later in the processing and thus cannot predetermine lexical access.

Another important addition in the BIA+ model is the introduction of phonological representations which get activated almost in parallel with the activation of the orthographic representations. Dijkstra et al. (1999) supported this notion when they provided empirical evidence confirming that phonology gets activated in visual language processing.

3. LSOCs and reduction of language switch cost

BIA+ model predicts that the inhibitory effect of the language switch can be overcome with the help of LSOCs because they may allow for the bottom-up restriction of the initial set of lexical candidates to just one (the appropriate) language (Van Heuven, Dijkstra 2002: 183). As far as LSOCs in Croatian and English are concerned, these two languages have most letters of their alphabets in common, but each of them also has some additional letters which are inexistent in the other language of the bilingual (Croatian: *č, ć, đ, š, ž* and English: *q, w, x, y*). These letters can serve as LSOCs in the experimental setup of the switch control attempt in the bilingual processing of these two languages. The hypothesis is that LSOCs may direct language access to the elements of the appropriate language in the mental lexicon (thus facilitating mapping form onto lexical entries) in bilingual language processing which is then reflected in reduced reaction times (RTs) in the language switch condition. If lexical access is directed to the elements of the appropriate language, it is referred to as language-selective access. If elements of both languages are activated, one speaks about language-nonselective lexical access. If LSOCs could direct processing to the elements of the appropriate language, such facilitation would rest upon the bottom-up processing mechanisms; the influence of form itself as opposed to top-down contextual influences. In this study both words and pseudowords are used as stimuli. Pseudowords are strings of letters which agree with the phonotactics of a particular language but do not have any meaning (e.g. *pijeka* for Croatian or *gath* for English). The usage of pseudowords as visual stimuli allows one to study the influence of form devoid of meaning and the influence of purely bottom-up processes on language processing.

4. Research aim and hypotheses

The aim of the research was to establish if letter-based LSOCs can speed up the processing of Croatian and English stimuli in the language-switch condition. Three hypotheses were set:

1. In the switch condition RTs to words with LSOCs will be faster than RTs to words without LSOCs.
2. In the switch condition RTs to pseudowords with LSOCs will be faster than RTs to words without LSOCs.
3. Generally, RTs to the stimulus will be slower in the switch condition than in the non-switch condition.

5. Research methodology

5.1. *Target stimulus*

Both Croatian and English stimulus consisted of 5-8-letter long nouns presented in their nominative forms. The frequency of each word was 75 or more tokens in a million and they did not have a more frequent orthographic neighbour[2] in the language they belonged to. The chosen nouns were divided into stimuli with LSOCs and without LSOCs in either English or Croatian languages (Table 1). LSOCs involved letters *č, ć, đ, š, ž* for Croatian and *q, x, y, w* for English. The words without LSOCs had combinations of graphemes found in the orthography of the other lan-

[2] Orthographic neighbors are those words which can be generated by replacing only one letter of the original word while the positions of the other letters are kept intact (e.g. *cat*, *mat*, *cap*).

guage so as to avoid possible directing of processing to the appropriate language on the basis of language-specific grapheme combinations. Approximately half of the words in each stimulus group were concrete nouns and the other half were abstract nouns.

Pseudowords were generated from the nouns used in the experiment by replacing the word-initial, within-word or word-final consonantal phoneme with another which differed from the original one in four distinctive features and created an orthographically possible combination with the surrounding graphemes in the language of origin. The pseudowords formed four groups to match the word stimuli (Table 1). Orthographic neighbourhood of the pseudowords was controlled.

Table 1. Target stimulus design.

	Croatian	N	English	N
words	without LSOCs	30	without LSOCs	30
	with LSOCs	30	with LSOCs	30
pseudowords	without LSOCs	30	without LSOCs	30
	with LSOCs	30	with LSOCs	30
Total N of stimuli	Croatian	120	English	120

5.2. *Non-target stimulus*

Additional stimulus items were chosen to function as “conditioners”. In this paper the term “conditioner” is used to denote those (existing) words which preceded the stimulus items to create the desired condition. The switch condition was defined as preceded by the same language word (not pseudoword). To condition the 120 Croatian and 120 English target stimuli, 120 Croatian and 120 English conditioners were chosen. Finally, to overcome the resulting greater number of words than pseudowords needed for the stimulus, 60 Croatian pseudowords and 60 English pseudowords were used as fillers. Also, 20 Croatian and English words and pseudowords were chosen for practice. The number of stimuli thus amounted to 620 items.

5.3. *Experimental design*

Conditioners and target stimuli were paired up to achieve the 16 possible combinations of the following conditions: Croatian/English item, with/without LSOCs, word/pseudoword, switch/nonswitch condition. The order of the conditioner-target pairs and fillers was randomized. Once randomized, the order of stimuli was fixed and presented to the participants.

5.4. *Participants and task*

A total of 20 third year students of English participated in the experiment. They were proficient English language speakers who used English on a regular basis for their education. They were tested with the Oxford Placement Test and their English language knowledge was found to be at level C1 or higher. The participants were seated in separate booths at computers on which the experiment was run. They were presented with stimuli, words or pseudowords in either Croatian or English. They carried out a lexical decision task; they had to decide if each presented letter string was a word in one of their languages or not and respond as quickly as possible by pressing keys 1 or 2 on the keyboard using the index and middle finger of their more dextrous hand. RTs to their answers were measured in milliseconds. They were instructed to respond to all the items presented, and they knew no difference between the practice items, conditioners and targets. Since the number of stimuli was great (600 conditioners and targets + 20 items used for practice), they were presented to the participants in three instances of 200 items, in between of which they were allowed a break. At the beginning of every instance they were presented with practice items. In order to control the better-finger effect, half of the participants (N=10) were asked to respond using the key “1” for a word and “2” for a pseudoword and the other half (N=10) were instructed to use the reversed keys. The order of the three parts of the experiment was also alternated to ensure that not all the participants were presented with the stimulus items in the same order. The experiment was presented and RTs measured with the E-Prime psychological software tool (Schneider et al. 2002a and b).

6. Results and discussion

Normal distribution of data was found. In spite of the small number of participants (which is a limitation of this study), the analysis of variance was carried out with RTs of the correct answers to allow for an insight into any occurring interaction of the independent variables. Not surprisingly, the main effect of language was found; RTs to Croatian stimulus were significantly faster than the RTs to the English stimulus ($F = 36.47$; $df = 1/19$; $p<0.01$). This was in accordance with the temporal delay assumption (BIA+ model), according to which L2 phonological and semantic codes are delayed in activation in comparison with L1 codes. Also, as expected, the main effect of word type was found as RTs to words were significantly faster than the RTs to pseudowords ($F = 54.90$; $df = 1/19$; $p<0.01$). There were no other main effects or interactions found. There was ***no switch cost effect*** either.

Both the first and second hypotheses were disproven as RTs to the stimulus with LSOCs were no faster than the RTs to the stimulus without LSOCs in the switch condition in the case of both words and pseudowords. Such results in participants' reactions to pseudowords showed that semantics did not influence the results obtained in the case of words. The most important and least expected result is the fact that no effect of the language switch was found. Such results require rethinking of the language switch effect in the case of Croatian-English dominant bilinguals.

At first sight, it might seem that the obtained no effect of LSOCs in the switch condition supports the language-nonselective access hypothesis to the mental lexicon of the studied speakers. However, the unexpected lack of the language switch cost (both in stimuli with and without LSOCs) seems to point at the possibility of language-selective lexical access in bilingual visual processing, which is possibly restricted to the dominant bilingual profile of the speakers of typologically very different languages in this particular type of experiment.

Interestingly enough, the results of this study are in accordance with the results obtained in the studies of ***auditory*** processing in the same profile of the Croatian-English bilinguals. Cergol Kovačević (forthcoming) had participants react to auditory stimulus in three language sets: monolingual Croatian, monolingual English and bilingual (mixed).[3] She did not control the switch condition as the stimuli were presented to the participants in random order. However, no statistically significant difference was found between the RTs to the same stimulus presented in the monolingual and the bilingual sets, for English and Croatian alike. This was interpreted as the lack of the switch cost effect in auditory processing in Croatian-English dominant bilinguals and was accounted for by the language-specificity of the phonologies of the two languages studied. It seemed that the LSCs in phonology had directed processing to the elements of the appropriate language and annihilated the language switch cost. Phonology is known to have a role in the reading process of bilinguals (Brysbaert, Van Wijnendaele 2003). It might the phonology, not orthography that helps overcome the language switch cost in visual processing. Phonology is by default language-specific and differentiating in various languages.

[3] See Cergol Kovačević (forthcoming) for the borderline interaction which, however, was not statistically significant.

7. BIA and BIA+ models and LSOCs in Croatian-English dominant bilinguals

Going back to the original models upon which this study was based, a possible interpretation of the results is laid out. Apparently, there seemed to be no influence of the previously processed language on the other language at the moment of the language switch in this study. This should exclude the prediction of the BIA model according to which the activation of the language nodes feeds that activation down to the lower processing levels of the same language thus aiding word recognition in the given language and inhibiting it in the other language. Rather, the obtained control of the language switch may be accounted for by the task/decision mechanism, as the BIA+ model predicts. In the presentation of the BIA+ model, Dijkstra and Van Heuven (2002) suggested that the identification system feeds constant output to the task/decision system. Task/decision system is likely to use that information for the selection of the appropriate response. In other words, the participants adjust their task/decision system to the requirements of the task. It is not difficult to imagine that such a system could use the information about the bilingual stimulus list in the same way and expect both languages in the stimulus.[4] Participant expectations are known to influence the response of the participants (e.g. Cheng, Howard 2008). Being set to expect bilingual processing and common language switches, the bilingual condition helps the participants keep both their languages active and prepared for the switch, which helps reduce the switch cost. This would support the belief that the language switch is controlled from outside the lexicon.

The question remains as to how the processing gets directed. The answer may lie in the combination of the BIA+ model's proposition about the coactivation of phonology and orthography (also in solely visual processing) and the propositions of the BIMOLA model, designed to account for auditory processing.

8. BIA + and BIMOLA models accounting for no switch effect

BIMOLA (Bilingual Model of Lexical Access) model was first proposed by Grosjean in 1988 and later extended by Léwy and Grosjean (unpublished) (Grosjean 2008). The model presupposes the existence of three levels of nodes: the feature level nodes (shared between the two languages), the phoneme and the word level nodes (organized separately between the languages). Each language is represented

[4] It should be noted here that Dijkstra and Van Heuven (2002) oppose to such an extension of the task/decision system's activity as they believe that the task/decision system cannot affect the relative language activation in the identification system.

as a separate subset, but they both belong to one larger system. The activation between the feature and phoneme levels flows bottom-up, and between the phoneme and word levels in both directions. There is also the top-down influence of the external information about the listener's language mode (particular language activation) and higher linguistic information (context). Phonotactic activation is present at the phoneme level. Grosjean (1997) suggests that phonetic specificities of the spoken language may increase the global activation of the appropriate language and speed up word recognition in that language. This corresponds with the results of this research in which it seems that already at the phoneme level (activated upon the activation of the level of orthography as predicted in BIA+) phonological language-specific information is identified, processed and used to direct the processing, thus annihilating the language switch cost.

An integration and adaptation of the BIA + and the BIMOLA models is suggested in order to capture the lack of the switch cost effect in the case of Croatian-English bilingual visual language processing. In accordance with the BIA+ model, the integrated model predicts the activation of the prelexical orthography level (letter level) on the basis of visual input. The activation of orthography immediately sets off lateral activation at the level of prelexical phonology (phoneme level). LSOCs get processed at the prelexical orthography level. However, they have no influence on the selectiveness of processing as all elements encountered at the level of prelexical phonology are language-specific in the case of English and Croatian languages which are typologically very much different. Thus, as BIMOLA proposes, bottom-up processing can be language-selective already at the level of prelexical phonology. Moreover, the bilingual context in which language switch is expected helps annihilate the switch cost (top-down processing). For the mentioned reasons, no language switch cost is found. Thus, LSOCs can play no role in the reduction of the already non-existing language switch cost. Moreover, it was interesting to find no influence of the LSOCs on the processing even when the semantics was missing (pseudowords). This should point to the inability of directing lexical access by means of LSOCs whatsoever.

9. Conclusion

Two important conclusions need to be pointed out in this research. The first one is the confirmed role of the expectancy of the language switch which reduces the switch cost in visual bilingual language processing. The common switch condition in such a processing situation keeps both linguistic systems highly alert, by means of the top-down information, the bilingual language context. The second one is the similarity between the processing effects found in the visual and spoken language processing, which suggests the role of the parallel activation of phonology in visual perception. This effect has already been incorporated into the BIA+ model of visual language processing. However, it seems that such bottom-up processing which incorporates the role of phonology in visual processing and the language-selective nature of phonology-based spoken language processing (as expressed in BIMOLA model) when combined with the top-down language-switch expectancy based on the bilingual language mode condition yields no switch cost effect in Croatian-English dominant bilinguals. The level of the participants' English language knowledge needs to be taken into account as well. They were proficient speakers of English who probably switch between their two languages rather easily, so the advantage of the language of previous stimulus in the processing of such speakers is not as great as it had earlier been suggested.

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MAPIRANJE VIZUALNA UNOSA NA LEKSIČKE JEDINICE U DVOJEZIČNOM MENTALNOM LEKSIKONU U UVJETU PROMJENE JEZIKA

U radu se proučava utjecaj jezično specifičnih elemenata u vizualnom podražaju na reakciju dominantnih dvojezičnih govornika u trenutku prebacivanja jezika procesiranja. Proučavaju se postavke modela dvojezičnog procesiranja BIA i BIA+ u smislu njihovih različitih gledanja na razloge utroška vremena pri prebacivanju jezika te njihovih pretpostavki o unutarjezičnim i izvanjezičnim utjecajima na dvojezično procesiranje. Hrvatsko-engleski dominantni dvojezični govornici pristupili su zadatku leksičke odluke u kojem su kontrolirane četiri nezavisne varijable: jezik podražaja (hrvatski/engleski), trenutak prebacivanja jezika (prebacivanje/bez prebacivanja), jezična specifičnost vizualnih elemenata podražaja (jezično specifični/jezično nespecifični) i tip podražaja (riječ/pseudoriječ). Istražena je interakcija navedenih varijabli te su uspoređena vremena reakcija ispitanika na podražaj s jezično specifičnim elementima i bez njih u trenutku prebacivanja jezika te u trenutku kad se jezik procesiranja nije mijenjao. Rezultati su pokazali da jezično specifični elementi u podražaju nisu imali utjecaja na trenutak promjene jezika, no nije pronađen ni utrošak vremena pri prebacivanju jezika. Rezultati su interpretirani u okviru postavki modela BIA+ u koji su integrirane temeljne postavke modela auditivnog dvojezičnog procesiranja BIMOLA kako bi se interpretirali rezultati vizualnog procesiranja hrvatsko-engleskih dominantnih dvojezičnih govornika koji su dobiveni u ovome istraživanju.

Ključne riječi: utrošak vremena pri prebacivanju jezika; jezično-specifični elementi; hrvatsko-engleski dominantni dvojezični govornici; BIA, BIA +; BIMOLA.